ROHINI COLLEGE OF ENGINEERING AND TECHNOLOGY
AUTONOMOUS INSTITUTION
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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

VII Semester

AU3008 Sensors and Actuators

UNIT – 4 - AUTOMOTIVE ACTUATORS

4.7 Working principles, construction of Stepper Motor

- Stepper motor is a brushless DC motor that rotates in steps.
- This unique motion makes stepper motor actuators ideal for applications where fine positioning and repeatable accuracy are required. T
- They're widely used in robotics, automation, CNC machines, 3D printers, and various industrial processes.
- **Step angle**

  Step angle is defined as the angle through which the stepper motor shaft rotates for each command pulse. It is denoted as β.

  Formula for step angle (β)

$$\beta = \frac{N_s - N_r}{N_s \cdot N_r} \times 360$$

$$\beta = \frac{360}{mN_r}$$

Where

Ns – No. of stator poles or stator teeth

Nr – No. of rotor poles or rotor teeth

m – No. of stator phases

Construction of Stepper Motor:

- Stepper motor is made up of the stator and rotor.

- ❒ The rotor is the movable part which has no winding, brushes and a commutator.
- ❒ The stator is made up of multipole and multiphase winding, usually of three or four phases winding wound for a required number of poles decided by desired angular displacement per input pulses.

<u>Components of a Stepper Motor</u>:

1. **Stator:**

    - ❖ The stationary part of the motor.
    - ❖ Consists of a stack of laminated iron cores with windings wound around them.
    - ❖ The number of windings and their arrangement determine the motor's step angle and resolution.

2. **Rotor:**

    - ❖ The rotating part of the motor.
    - ❖ Can be of two main types:

    - ❖ **Permanent Magnet (PM) Rotor:** Contains permanent magnets that interact with the magnetic fields generated by the stator winding
    - ❖ **Variable Reluctance (VR) Rotor:** Consists of a soft iron core with teeth that align with the stator poles to minimize magnetic reluctance.

3. **Bearings:**

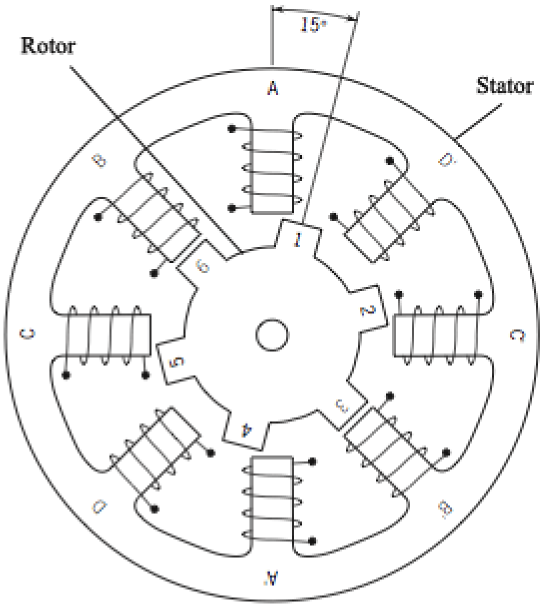
    Support the rotor and allow for smooth rotation with minimal friction.

4. **End Caps:**

    Enclose the stator and rotor assembly, providing structural support and protection.

- ❒ Coils are arranged in terms of coil pairs, like A and A’ forms a pair B and B’ forms a pair and so on.

- So each of this coil pair's form an electromagnet and they can be energised individually using a driver circuitry.



- **When a coil gets energised it acts as a magnet and the rotor pole gets aligned to it, when the rotor rotates to adjust itself to align with the stator it is called as one step.**
- Similarly by energising the coils in a sequence we can rotate the motor in small steps to make a complete rotation.

Working of Stepper Motor:

- **Electromagnetic Interaction**:
  - Stepper motors have a **stator** with multiple windings (electromagnetic coils) and a **rotor** with magnetic poles or teeth.
  - When the stator windings are energized in a sequence, they create magnetic fields that pull or push the rotor into alignment with each successive magnetic field.
- **Stepwise Rotation**:

- The current is applied in pulses to the stator windings, producing distinct **steps** of movement.
- The **step angle** is the degree of rotation the motor moves with each pulse and depends on the motor's construction. A typical step angle is 1.8° (200 steps per revolution).

- **Phased Energizing**:

  - Stepper motors operate based on a sequence called **phasing**—a specific pattern of energizing coils to create a rotating magnetic field.
  - By adjusting the order and timing of current pulses, the rotor can move forward or backward in small, controlled steps.

- By controlling the sequence of energizing the electromagnets, the direction of rotation can be controlled.
- Varying the number of steps per pulse gives finer position resolution. Higher number of steps per pulse means smaller angular rotation per step.

Step Angle in Stepper Motor:

Step angle is defined as the angular rotation produced by the stepper motor per pulse given as input. A standard step angle varies between 1.8° to 0.9°. Smaller the step angle, better the positional accuracy and higher the number of steps per revolution.

$$\text{Resolution} = \frac{\text{number of steps}}{\text{number of revolutions of the rotor}}$$

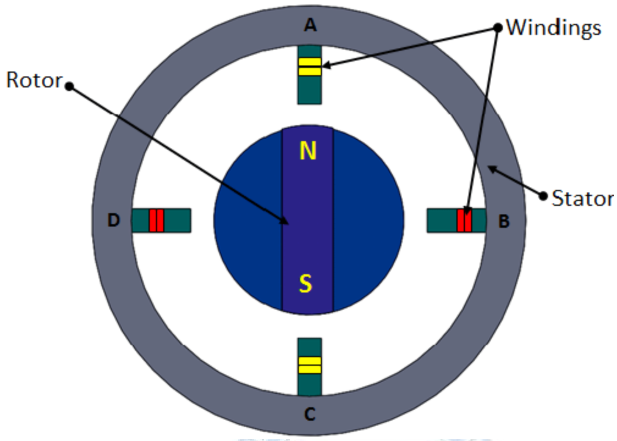
Common step angles of 1.8° gives a resolution of 200 steps/revolution while 0.9° gives 400 steps/revolution. Micro stepping techniques can produce step angles less than 1° for high precision applications.

Types of Stepper Motors:

1. Permanent Magnet Stepper Motor

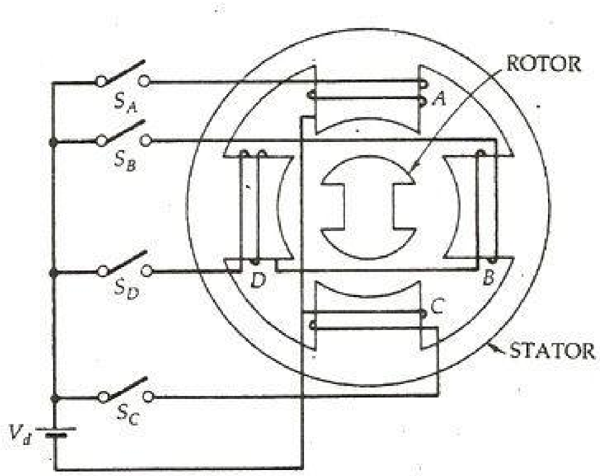
- **Construction**: Uses a rotor made of a permanent magnet.

- **Operation**: The rotor aligns with the magnetic field generated by the stator coils when energized in sequence. Each step occurs as the rotor poles are attracted to the stator poles.
- **Characteristics**: Provides good torque at low speeds, has a basic design, and offers relatively simple control.
- **Common Applications**: Printers, scanners, and low-speed robotics.



2. Variable Reluctance Stepper Motor

- **Construction**: The rotor is a toothed iron core with no permanent magnet. The stator has multiple electromagnetic poles with coils.
- **Operation**: Works on the principle of magnetic reluctance; the rotor aligns with the lowest reluctance path formed by the energized stator coils. The stator's magnetic field changes direction step-by-step, pulling the rotor teeth into alignment.
- **Characteristics**: Fast response, high resolution, and low torque. Typically used for applications requiring low power.
- **Common Applications**: Positioning applications like gauges and automotive instrument clusters.



3. Hybrid Stepper Motor

- **Construction**: Combines features of both permanent magnet and variable reluctance motors. The rotor consists of a toothed permanent magnet, and the stator has a complex winding pattern.
- **Operation**: The stator coils create a rotating magnetic field, and the rotor's toothed magnetic poles align with it. This type achieves very fine steps and high torque.
- **Characteristics**: High accuracy, better torque, smaller step angles (up to 0.9°), and more efficient. This type is widely used in applications needing high precision.
- **Common Applications**: CNC machines, 3D printers, medical equipment, and robotics.

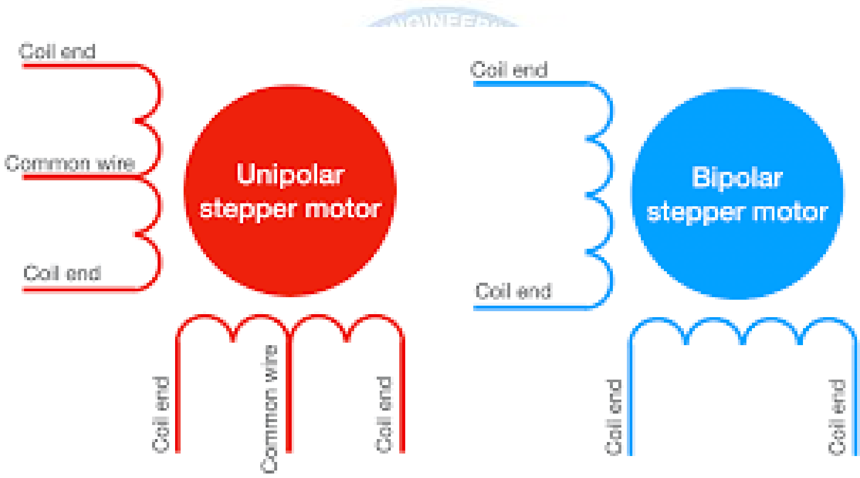
4. Unipolar Stepper Motor

- **Construction**: Has a single winding per phase with a center tap, which allows the current to flow in only one direction in each half of the winding.
- **Operation**: By switching the current between the two halves of the winding, the motor steps forward. The simplicity in controlling current flow makes unipolar motors easier to drive.
- **Characteristics**: Lower torque than bipolar stepper motors, simpler control circuits, and generally cost-effective.

- **Common Applications**: Low-power applications, such as small robots and hobby projects.

5. Bipolar Stepper Motor

- **Construction**: Has a single winding per phase, but without center taps. Requires reversing the current direction in each phase to step.
- **Operation**: To move the rotor, the driver reverses the polarity of the current in the stator windings. This requires a more complex driver circuit than a unipolar motor.
- **Characteristics**: Higher torque and efficiency than unipolar stepper motors due to the use of the entire winding.
- **Common Applications**: Industrial applications, 3D printing, robotics, and where high torque is needed.



6. Closed-Loop Stepper Motor

- **Construction**: Similar to a standard stepper motor, but equipped with a feedback device, like an encoder.
- **Operation**: Operates with a feedback control system, enabling real-time adjustments to motor position based on the feedback.
- **Characteristics**: High accuracy, no lost steps, smoother motion, and less heat generation due to lower power consumption.
- **Common Applications**: Applications needing high reliability and precision, such as medical equipment, robotic arms, and automated manufacturing.

Applications:

- CNC Machines
- Pick-and-Place Robots
- 3D Printing and Additive Manufacturing
- In robotics, Arm Movement and Joint Control
- Headlight Levelling and Mirror Adjustment
- **Throttle and Valve Control**
- Satellite Antenna Positioning
- Washing Machines, Refrigerators

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